

Composted and Noncomposted Manure Application to Conventional and No-Tillage Systems: Corn Yield and Nitrogen Uptake

Bahman Eghball* and James F. Power

ABSTRACT

Manure application to the soil surface may not be as effective as incorporated manure for crop production, because of potential N loss. An experiment was conducted to determine the effects of composted (compost) and noncomposted manure from beef cattle (*Bos taurus*) feedlots on corn (*Zea mays* L.) yield and N uptake under two tillage systems in 4 years. Conventional and no-till systems were used as main plots, and subplots consisted of application of composted and noncomposted manure and fertilizer to provide for corn N requirements, and check treatments. Manure and compost were applied and immediately incorporated by disking in the conventional system and left on the surface in the no-till. Fertilizer was incorporated in the conventional system and surface-applied in the no-till system each spring prior to planting. Results showed that in 3 out of 4 years there was no effect of tillage on corn grain yields of plots receiving manure or compost. Manure and compost application resulted in similar grain yield as that for fertilizer treatment in all years except for no-till in 1996. First-year N availability was approximately 38% for manure and 20% for compost in both tillage systems. Apparent N use efficiency was 17% for manure, 12% for compost, and 45% for the fertilizer treatment across 4 years. Chlorophyll meter readings, indicating relative plant N concentration at different stages of growth, were closely related to N uptake and grain yield in years with adequate water supply, but not in the drier year of 1995. Stalk NO_3^- -N concentration at harvest was above the critical level of 2000 mg kg^{-1} for the fertilizer treatment in 1995 but was low ($<200 \text{ mg kg}^{-1}$) for manure and compost treatments. Stalk NO_3^- -N concentration did not exceed the critical level for any treatment in other years. When the correct N availability factor is used, beef cattle feedlot manure and compost can be effectively utilized in no-till corn production systems.

IN THE UNITED STATES, beef cattle feeding is concentrated in the central and southern Great Plains. Leading states are Texas, Nebraska, Kansas, Iowa, and Colorado, which collectively finish two-thirds of the beef fed in the United States. Approximately 84% were fed in feedlots with a capacity of 1000 or more head (Krause, 1991). Handling and utilizing the manure produced in these large feedlots is a significant environmental problem that must be addressed. Manure from these confined animal feeding units is an important resource for crop production and soil sustainability, in that it is a source of all essential plant nutrients. This manure also provides an excellent source of organic matter when added to soils, restoring some of the organic matter depleted by many agricultural practices. However, manure produced by beef cattle can potentially be a source of pollution for water, air, and land pollution, because

of the potential for excess nitrates, salts, undesirable microorganisms, pathogens, and greenhouse gases; it is also a possible source of weed seed (Eghball and Power, 1994).

Composting manure produces a stabilized product that can be stored or spread with little odor or fly breeding potential (Sweeten, 1988; Rynk et al., 1992). Other advantages of composting include killing pathogens and most weed seeds, and improving handling characteristics of manure by reducing volume and weight. Disadvantages of composting include nutrient loss, specifically N, and requirements for time, money, equipment, and labor (Rynk et al., 1992). Eghball et al. (1997) found that as much as 40% of total beef feedlot manure N can be lost during composting, and significant losses of K and Na ($>6.5\%$ of total K and Na) occur in runoff from composting windrows not protected from rainfall.

The no-till crop production system is becoming more common in the United States. It was predicted that by the year 2000, 45% of U.S. cropland will be under no-till or reduced tillage systems (USDA, 1975). In 1996, 41% of the U.S. cropland was under no-till or reduced tillage management (CTIC, 1997). Soil protection from erosion losses, conservation of soil water by increased infiltration and decreased evaporation, increased use of land too steep for conventional production, and reduction in fuel, labor, and machinery costs are among the reasons for increased use of reduced tillage systems (Doran and Linn, 1994). Manure application to no-till can result in increased residue on the surface and may reduce soil erosion. Woodruff et al. (1974) showed that manure can reduce soil wind erosion. However, manure application to no-till, where no incorporation is done, may reduce its effectiveness as a nutrient source because of potential N loss.

Beef cattle feedlot manure is different from other livestock manure, as it is left on the feedlot surface for up to 1 year before it is collected. About 50% of the excreted N is lost, primarily by NH_3 volatilization, by the time manure is collected in cattle feedlots (Gilbertson et al., 1971). The remaining N is in a more stable form and not subject to a great N loss. In composting, an additional 20 to 40% of the manure N is lost and the N in compost is in even more stable forms than in typical beef cattle feedlot manure (Eghball et al., 1997). In dairy, swine (*Sus* sp.), or poultry (*Gallus* and other spp.) manure, up to 50% of the total N is in the NH_4 form and subject to loss as NH_3 if manure is surface-applied and not incorporated immediately (Overcash et al., 1983). In compost and beef cattle feedlot manure, NH_4^+ -N usually accounts for less than 16% of total N, and potential NH_3 loss will not significantly reduce the N value of manure or compost (Eghball and Power, 1999).

Poultry and dairy manure have been applied in no-

Dep. of Agronomy and USDA-ARS, Univ. of Nebraska-Lincoln, Lincoln, NE, 68583. Joint contribution of the USDA-ARS and the Univ. of Nebr. Agric. Res. Div., Lincoln, NE, as Journal Series no. 12222. Received 1 Sept. 1998. *Corresponding author (beggball@unl.edu).

till systems. Poultry manure application resulted in significantly greater corn grain yield for a conventional than a no-till system (Sims, 1987). This may be because $\text{NH}_4^+\text{-N}$ was about 24% of the total N in the poultry manure used, and NH_3 volatilization reduced the amount of N available to the crop in the no-till soil. Soil NO_3^- , soil NH_4 , and $\text{NO}_3\text{-N}$ leaching losses to the 0.6-m depth were greater with N fertilizer than with poultry manure, but the residual N remaining in the soil was greater with poultry manure than fertilizer (Sims, 1987). Injected liquid dairy manure in no-till and chisel plow systems resulted in similar corn grain yield when applications were made annually, but yield was greater with plow than no-till in the second year when biennial manure applications were made (Joshi et al., 1994a). Soil water collected at a depth of 1.5 m had an average $\text{NO}_3\text{-N}$ concentration of 66 mg L^{-1} for annual inorganic fertilizer, 50 mg L^{-1} for annual manure, and 11 mg L^{-1} for biennial manure application in 2 years (Joshi et al., 1994b).

Incorporation of manure after application may reduce runoff losses and conserve manure nutrients compared with surface application. Loss of nutrients from surface application of manure or compost containing high NH_4 contents may reduce their effectiveness for crop production. Our objective was to determine the effects of composted and noncomposted beef cattle feedlot manure application on corn grain yield and N uptake in conventional and no-tillage systems.

MATERIALS AND METHODS

An experiment was initiated in 1992 on a Sharpsburg silty clay loam soil (fine, smectitic, mesic Typic Argiudoll) under rainfed conditions at the University of Nebraska Agricultural Research Center near Mead, NE. The soil had a Bray and Kurtz no. 1 P test of 79 mg kg^{-1} and a pH (1:1 soil:water) of 6.3 in the surface 15 cm. A split-plot in a randomized complete block design was used with four replications. Tillage systems of conventional and no-till were used as main plots. Subplots consisted of application of composted and noncomposted beef cattle feedlot manure and commercial fertilizer to provide for corn N requirements (151 kg available N ha^{-1} for an expected 9.4 Mg ha^{-1} grain yield; Gilbertson et al., 1979), and a nonfertilized check. Manure and compost were applied and incorporated within 1 or 2 d into the top 10 cm of soil by disking in the conventional tillage plots in the autumn of 1992, 1993,

1994, and 1995. The conventional plots were also cultivated for weed control, in addition to using herbicide in the corn rows. In the no-till plots, manure and compost were broadcast on the soil surface in the autumn without incorporation or subsequent tillage. Weed control in the no-till plots was achieved using herbicides. Nutrient contents of the applied manure and compost are given in Table 1.

Nitrogen and P fertilizers were applied each spring to both tillage systems prior to disking of the conventional tillage area and subsequent planting. Diammonium phosphate (18-20-0 N-P-K) was applied at a rate of 25.8 kg P ha^{-1} , and additional NH_4NO_3 (34-0-0 N-P-K) was applied to provide a total N rate of 151 kg N ha^{-1} , for an expected yield level of 9.4 Mg ha^{-1} (Gilbertson et al., 1979). The limiting nutrient in this study was N. Application of P fertilizer was based on manure and compost P additions, while accounting for P removal in grain. Check plots received no manure, compost, or chemical fertilizer. Manure and compost were applied in 1992 based on the assumption that 40, 20, 10, and 5% of the N applied would be plant-available in the 1st, 2nd, 3rd, and 4th year after application, respectively (Gilbertson et al., 1979; Eghball and Power, 1999). This assumption was found to be an overestimation of N availability from compost, since N availability from compost was approximately 20% based on plant N uptake in 1993. Therefore, N availability from compost was changed to 20, 20, 10, and 5% in the 1st, 2nd, 3rd, and 4th year after compost application. The 40, 20, 10, and 5% N availability assumption was used for manure in all years. The residual values of N from previous manure and compost applications were considered when these resources were applied in the 2nd, 3rd, and 4th year. Nitrogen availability from manure and compost beyond the 4th year was assumed to be minimal.

Manure or compost was hand-applied to 12.2- by 4.6-m plots (6 corn rows) after corn harvest in late autumn (Nov.-Dec.). Manure and compost characteristics are given in Table 1 and the application rates are given in Table 2. Corn (Pioneer 3394) was planted at a seeding rate of 47 000 seed ha^{-1} and a 0.76-m row spacing. The planting dates were 21 May 1993, 10 May 1994, 24 May 1995, and 21 May 1996.

Plant samples (4 plants per plot) were collected at the 10-leaf stage and at tasseling each year. The samples were dried at 70°C, weighed, and analyzed for total N (Scheepers et al., 1989). Corn was harvested by hand in October (middle two rows, 6.1 m long) of each year and grain yield determined. The reported yields are adjusted to 155 g kg^{-1} water content. Stover samples were taken from one of the two rows used for grain determination. Grain and stover samples were analyzed for N content to determine total N uptake. Stalk samples (20 cm long each) were taken at 15 cm above ground from each plot (8 per plot) at harvest time, dried, ground to pass a 0.5-mm sieve, and analyzed for $\text{NO}_3\text{-N}$ (Binford et al., 1990).

Chlorophyll meters (Minolta SPAD 502) were used to evaluate the N status of corn during the growing season.¹ Measurements were made at the 10-leaf stage and once every 2 wk

Table 1. Characteristics of beef cattle feedlot manure and composted feedlot manure applied in 4 years at Mead, NE. Nutrients, C, and ash contents are on a dry weight basis.

Year and source	Total				Water		$\text{NO}_3\text{-N}$	$\text{NH}_4\text{-N}$	EC†	pH†
	C	N	P	Ash	content					
	g kg^{-1}						mg kg^{-1}			
1992										
Manure	78.4	7.9	3.20	844	195	30	1263	4.6	7.3	
Compost	95.0	11.0	6.60	808	332	117	169	7.4	7.7	
1993										
Manure	133.1	10.2	4.00	715	539	17	480	5.2	8.8	
Compost	87.4	7.7	2.15	796	403	38	33	2.2	8.3	
1994										
Manure	237.0	15.6	3.27	591	200	11	365	5.4	8.2	
Compost	73.5	7.6	4.07	849	340	383	55	6.1	7.2	
1995										
Manure	172.8	13.0	3.16	677	251	130	898	3.8	7.3	
Compost	68.2	7.8	3.05	798	150	294	97	6.0	7.7	

† Electrical conductivity (EC) and pH were determined on 2:1 water to dry manure or compost ratio.

Table 2. Composted and noncomposted manure dry weight and N application in 4 years at Mead, NE.

Treatment	1992	1993	1994	1995	Total
Dry weight applied					
Manure, Mg ha^{-1}	46.9	18.5	12.1	14.5	92.0
Compost, Mg ha^{-1}	34.6	49.5	25.1	36.4	145.6
N applied					
Manure, kg N ha^{-1}	378	189	189	189	945
Compost, kg N ha^{-1}	378	378	189	283	1228
Fertilizer, kg N ha^{-1}	151	151	151	151	604

¹ Use of a trade name does not indicate endorsement by the USDA-ARS or the Univ. of Nebraska.

thereafter, for a total of four times per year (three measurements in 1995). Measurements were made (30 random plants per plot) on the top fully expanded leaf at the 10-leaf stage and on the ear-leaf for subsequent measurements.

Growing season rainfall (1 May–15 Oct.) was 773, 558, 307, and 425 mm in 1993, 1994, 1995, and 1996, respectively, compared with a 30-yr average of 493 mm. Rainfall from 1 June to 31 August for the same four years was 595, 405, 107, and 215 mm, respectively. The plots were irrigated three times during July and August in 1995 for a total of 75 mm, to avoid losing the experiment.

Analysis of variance was used to analyze the data, using SAS (SAS Inst., 1985). Combined analysis was performed across years for all parameters except chlorophyll meter readings, which are reported for each year. Number of plants harvested was used as covariant in the analysis of variance to adjust grain yield and total N uptake for plant population differences among plots. A probability level ≤ 0.05 was considered significant.

RESULTS AND DISCUSSION

Grain Yield and Total N Uptake

Application of composted or noncomposted beef cattle feedlot manure resulted in greater corn grain yield than from nonfertilized check treatments in all 4 years (Table 3). Averaged across treatments, grain yield was greatest in 1994 and was least in 1995. The two tillage systems resulted in similar corn grain yield, but tillage interacted with year and treatment (Table 3). Grain yield was similar for no-till and conventional tillage systems for the four treatments in 1993, 1994, and 1995, but in 1996 yield was lower for the manure and compost treatments in no-till than in the conventional system (Fig. 1). There was slightly greater incidence of root worm (*Diabrotica* spp.) damage in the no-till than con-

ventional system in 1996, but use of damage ranking as a covariant failed to change the grain yield response observed (data not shown). In 3 out of 4 years, surface application of manure or compost in no-till resulted in corn grain yield comparable to that with manure and compost incorporation (conventional tillage system).

Total N uptake was greatest in 1993 and was least in 1995 (Table 3). There was no effect of tillage on total N uptake, but other treatments did influence total N uptake. There were significant year \times tillage and year \times treatment interactions for total N uptake (Table 3). Total N uptake was greater for conventional than no-till in 1994 and 1996, but this was reversed in 1995 (Table 4). Total N uptake was greatest for fertilized and was least for check plots in all years. Compost application resulted in N uptake similar to that for manured plots in all years except in 1993, when corn receiving manure had greater N uptake than corn receiving compost (Table 5). Greater grain yield and total N uptake for manure than compost in 1993 reflected the inadequate amount of compost applied (inadequate due to lower than expected N availability from compost). The significant tillage \times treatment interactions for grain yield and total N uptake indicate greater differences between fertilizer and manure or compost in no-till than in the conventional system (Table 6).

Apparent N use efficiency was calculated as [(total treatment N uptake in 4 yr – total check N uptake in 4 yr)/N applied in 4 yr] \times 100. This was 19.9% for manure, 13.7% for compost, and 42.4% for fertilizer in the conventional tillage system across 4 years. Corresponding values for no-till were 13.5, 11.1, and 47.7%, respectively. Assuming 100% N availability from fertilizer and similar N use efficiency of the available N from

Table 3. Tillage, manure, and composted manure effects on corn grain yield, total N uptake, plant weight and N uptake at the 10-leaf stage and at tasseling in 4 years and on stalk nitrate concentration in 3 years at Mead, NE.

Variable	n	Grain	Total N uptake	Stalk nitrate	10-leaf dry wt.	Tasseling dry wt.	10-leaf N	Tasseling N
		Mg ha ⁻¹	kg ha ⁻¹	mg kg ⁻¹	g plant ⁻¹			
Year								
1993	32	6.23†	99†	—	35	158	0.73	1.53
1994	32	7.49	94	90	55	170	0.97	1.84
1995	32	3.81	66	1150	69	108	0.81	1.20
1996	32	5.44	84	610	65	157	1.25	2.21
Tillage (Till)								
Conventional	64	5.86	88	550	54	149	0.93	1.79
No-till	64	5.62	83	670	59	147	0.95	1.60
Treatment (Treat)								
Manure (Man)	32	6.14	89	80	56	146	0.92	1.60
Compost (Com)	32	6.03	87	90	58	159	0.90	1.83
Fertilizer (Fert)	32	7.03	118	2240	65	172	1.29	2.30
Check	32	3.77	50	40	46	116	0.64	1.04
Analysis of variance	df				Pr > F			
Year	3 (2)‡	0.01	0.01	0.02	0.01	0.01	0.01	0.01
Rep(Year)	12 (9)							
Tillage	1	0.56	0.55	0.25	0.68	0.89	0.89	0.39
Year \times Till	3 (2)	0.03	0.02	0.52	0.01	0.01	0.01	0.01
Till \times Rep(Year)	12 (9)							
Treatment	3	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Man & Com vs. Fert	1	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Man vs. Com	1	0.48	0.72	0.95	0.30	0.07	0.70	0.09
Check vs. All	1	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Year \times Treat	9 (6)	0.01	0.01	0.01	0.25	0.04	0.21	0.03
Till \times Treat	3	0.01	0.01	0.81	0.14	0.02	0.04	0.17
Year \times Till \times Treat	9 (6)	0.02	0.19	0.99	0.25	0.65	0.56	0.88
Plant ha ⁻¹	1	0.01	0.02	—	—	—	—	—

† Least squares means adjusted for plant population differences. Plant ha⁻¹ was the covariant.

‡ The numbers in parentheses are df for stalk nitrate.

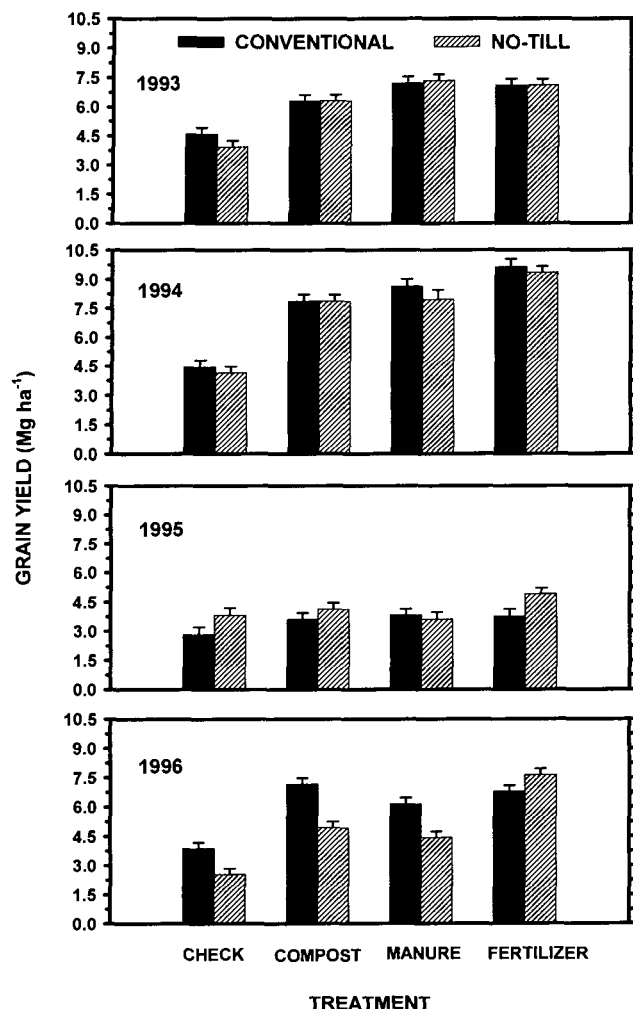


Fig. 1. Corn grain yield for four treatments in conventional and no-tillage systems in 4 years at Mead, NE. Vertical bars indicate standard errors (2 SE indicates 0.05 level probability).

manure and compost as those for the fertilizer, first-year N availability was approximately 38% for manure and 20% for compost in both tillage systems, based on total N uptake in 1993. Eghball and Power (1999) found first-year N availability from manure and compost to be 40 and 15%, respectively. Second-year N availability was 18.0% for manure and 8.4% for compost, based

Table 5. Year \times treatment interaction means for corn grain yield, total N uptake, stalk nitrate, plant weight, and N uptake at tasseling at Mead, NE.

Variable	Grain	Total N uptake	Stalk nitrate	Tasseling dry wt.	Tasseling N
	Mg ha ⁻¹	kg ha ⁻¹	mg kg ⁻¹	—— g plant ⁻¹ ——	
1993					
Manure	7.28 ± 0.23†	118 ± 5†	—	169 ± 8	1.59 ± 0.13
Compost	6.31 ± 0.23	93 ± 5	—	153 ± 8	1.54 ± 0.12
Fertilizer	7.10 ± 0.23	122 ± 5	—	187 ± 6	2.08 ± 0.17
Check	4.26 ± 0.25	63 ± 6	—	122 ± 3	0.90 ± 0.03
1994					
Manure	8.29 ± 0.33	94 ± 5	30 ± 10	165 ± 13	1.91 ± 0.29
Compost	7.87 ± 0.26	99 ± 6	10 ± 2	185 ± 10	1.91 ± 0.19
Fertilizer	9.49 ± 0.28	135 ± 6	290 ± 130	199 ± 9	2.44 ± 0.29
Check	4.29 ± 0.27	48 ± 6	10 ± 1	129 ± 11	1.12 ± 0.10
1995					
Manure	3.71 ± 0.25	61 ± 6	130 ± 50	111 ± 10	1.13 ± 0.14
Compost	3.87 ± 0.23	67 ± 5	180 ± 100	109 ± 11	1.31 ± 0.17
Fertilizer	4.33 ± 0.25	91 ± 6	4260 ± 850	120 ± 16	1.46 ± 0.16
Check	3.32 ± 0.27	47 ± 6	30 ± 5	93 ± 12	0.89 ± 0.14
1996					
Manure	5.29 ± 0.22	82 ± 5	20 ± 10	140 ± 20	1.79 ± 0.33
Compost	6.06 ± 0.22	91 ± 5	90 ± 10	189 ± 11	2.57 ± 0.25
Fertilizer	7.22 ± 0.23	123 ± 5	1430 ± 500	182 ± 11	3.24 ± 0.26
Check	3.20 ± 0.22	42 ± 5	80 ± 4	119 ± 12	1.25 ± 0.11

† Least squares means adjusted for plant population differences, ± 1 SE.

on corn N uptake in a biennial manure or compost application. Lower grain yield for compost in 1993 (Table 5) may reflect lower than expected N availability.

Plant Dry Weight and N Uptake at 10-Leaf and Tasseling

There were significant effects of treatment and year on plant weight and N uptake at the 10-leaf stage and at tasseling (Table 3). Compared with other study years, plant dry weight in 1995 was greatest at the 10-leaf stage, but was least at tasseling (Table 3). This probably occurred because of the dry condition that prevailed after the 10-leaf stage in 1995. Fertilizer application resulted in greater plant weight and N uptake at the 10-leaf stage and at tasseling than for all other treatments (Table 3). At tasseling, compost application resulted in greater plant weight and N uptake than manure application. There was no effect of tillage on plant weight and N uptake at the 10-leaf stage and at tasseling (Table 3).

There were tillage \times year interactions for plant weight and N uptake at the 10-leaf stage and at tasseling (Table 3). Plant weight and N uptake at both sampling times

Table 4. Year \times tillage interaction means for corn grain yield, total N uptake, plant dry weight and N uptake at the 10-leaf stage and at tasseling at Mead, NE.

Variable	Grain	Total N uptake	10-leaf dry wt.	Tasseling dry wt.	10-leaf N	Tasseling N
	Mg ha ⁻¹	kg ha ⁻¹	g plant ⁻¹			
1993						
Conventional	6.29 ± 0.20†	101 ± 4†	39 ± 2	165 ± 8	0.79 ± 0.07	1.61 ± 0.15
No-till	6.17 ± 0.16	96 ± 4	32 ± 2	151 ± 7	0.67 ± 0.06	1.45 ± 0.12
1994						
Conventional	7.65 ± 0.22	99 ± 5	59 ± 3	178 ± 9	0.98 ± 0.08	2.00 ± 0.22
No-till	7.33 ± 0.22	89 ± 4	52 ± 4	160 ± 11	0.97 ± 0.09	1.69 ± 0.17
1995						
Conventional	3.50 ± 0.18	59 ± 4	52 ± 4	89 ± 7	0.63 ± 0.07	1.04 ± 0.12
No-till	4.11 ± 0.18	74 ± 4	87 ± 4	128 ± 7	0.99 ± 0.09	1.36 ± 0.10
1996						
Conventional	6.00 ± 0.16	94 ± 4	66 ± 3	165 ± 10	1.32 ± 0.08	2.52 ± 0.25
No-till	4.89 ± 0.16	75 ± 4	65 ± 4	149 ± 14	1.19 ± 0.13	1.90 ± 0.25

† Least squares means adjusted for plant population differences, ± 1 SE.

Table 6. Tillage \times treatment interaction means for corn grain yield, total N uptake, 10-leaf N, and plant dry weight at tasseling at Mead, NE.

Variable	Grain yield Mg ha ⁻¹	Total N uptake kg ha ⁻¹	10-leaf N g plant ⁻¹	Tasseling dry wt.
Conventional				
Manure	6.45 \pm 0.16†	97 \pm 4†	0.99 \pm 0.10	161 \pm 9
Compost	6.24 \pm 0.16	92 \pm 4	0.90 \pm 0.10	152 \pm 12
Fertilizer	6.82 \pm 0.17	114 \pm 4	1.19 \pm 0.09	171 \pm 13
Check	3.93 \pm 0.16	50 \pm 4	0.65 \pm 0.06	114 \pm 10
No-till				
Manure	5.83 \pm 0.19	81 \pm 4	0.85 \pm 0.06	132 \pm 12
Compost	5.81 \pm 0.16	83 \pm 4	0.90 \pm 0.06	166 \pm 8
Fertilizer	7.25 \pm 0.16	121 \pm 4	1.40 \pm 0.12	174 \pm 8
Check	3.60 \pm 0.16	49 \pm 4	0.64 \pm 0.05	117 \pm 5

† Least squares means adjusted for plant population differences, ± 1 SE.

were greater for no-till than the conventional system in 1995, while the two tillage systems resulted in similar plant weight and N uptake in other years (Table 4). In the drier 1995, no-till resulted in greater early growth and yield than the conventional system, possibly reflecting greater water storage in no-till. There was a year \times treatment interaction for plant weight at tasseling and tillage \times treatment interactions for both plant weight at tasseling and N uptake at the 10-leaf stage (Tables 3, 5, and 6).

Plant weight and N uptake at the 10-leaf stage followed the same trend as grain yield and total N uptake for manure, compost, and fertilizer treatments in all years except the drier 1995. By tasseling, plant weight and N uptake closely followed grain yield and total N uptake trends, which indicates that early plant growth may not be a good indicator of yield or N uptake in dry years.

Stalk NO₃⁻-N

Stalk NO₃⁻-N concentration after harvest has been used as an indicator of excess soil NO₃⁻-N or induced environmental stress. The critical stalk NO₃⁻-N value is about 2000 mg kg⁻¹ (Binford et al., 1990; Varvel et al., 1997). Stalk NO₃⁻-N levels >2000 mg kg⁻¹ are judged to indicate excess NO₃⁻ in the soil or an occurrence of environmental stress. High soil NO₃⁻-N has the potential to leach into ground water. Stalk NO₃⁻-N <100 mg kg⁻¹ may indicate that N supply was not adequate to

obtain optimum corn yields (Binford et al., 1990). Stalk NO₃⁻-N was greater in 1995 than in the other years when averaged across tillage and treatments, but the concentration (1150 mg kg⁻¹) was below the critical level (Table 3). No effect of tillage on stalk NO₃⁻-N concentration was observed. There was a treatment \times year interaction for stalk NO₃⁻-N (Table 3). Stalk NO₃⁻-N was below the critical level for all treatments in 1994 and 1996, but in the drier year of 1995, stalk NO₃⁻-N was more than twice the critical level for the fertilizer treatment (Table 5). In the dry year, excess NO₃⁻-N in stalks indicated excess available N in the soil. However, when manure or compost are applied in dry years, less N is expected to convert to NO₃⁻-N in the soil and excess build-up of NO₃⁻ may not be a problem.

Leaf Chlorophyll

The chlorophyll meter measures the degree of greenness of the leaves and is an indication of plant N concentration in the growing season (Varvel et al., 1997). Leaf chlorophyll readings from manure, compost, and check treatments were compared with that from the fertilizer treatment. Check treatments had lower chlorophyll readings than the fertilizer treatments for all measurement times in both tillage systems in all 4 years (Table 7). Manure application resulted in generally similar chlorophyll meter readings to those for the fertilizer treatments in the conventional tillage system in all 4 years, but readings for manure treatments in no-till were reduced in all years. Compost application resulted in readings less than those for fertilizer treatments for both tillage systems in 1993 and in the no-till in 1994.

Chlorophyll meter readings for the times closest to plant samplings at the 10-leaf stage and at tasseling were correlated with plant weight and N uptake at these sampling times. Correlation coefficients between chlorophyll meter readings and plant dry weight or N uptake at both 10-leaf and tasseling stages indicated significant relationships in 1993, 1994, and 1996 (Table 8). The correlation coefficients at the 10-leaf stage between chlorophyll meter reading and plant weight or N uptake at the 10-leaf stage were low ($r < 0.20$) in 1995.

Chlorophyll meter readings can also indicate plant

Table 7. Manure, compost, and fertilizer effects on chlorophyll meter readings of corn in two tillage systems in 4 years at Mead, NE.

Variables	Chlorophyll meter reading															
	1993				1994				1995				1996			
	top leaf,		ear leaf		top leaf,		ear leaf		top leaf,		ear leaf		top leaf,		ear leaf	
	13 July	29 July	11 Aug.	24 Aug.	14 July	27 July	10 Aug.	29 Aug.	3 Aug.	22 Aug.	29 Aug.	15 July	29 July	12 Aug.	30 Aug.	
Conventional till																
Fertilizer	52	56	53	51	54	53	54	47	44	49	44	49	58	58	56	
Check	40	44	41	43	38	36	36	28	40	42	36	42	40	45	39	
Manure	49	54	52	53	50	49	48	43	44	47	44	47	54	52	51	
Compost	45	48	46	48	50	49	48	37	46	47	43	48	56	57	54	
LSD (0.05)	2	3	5	5	5	8	6	5	2	6	4	2	4	5	5	
No-Till																
Fertilizer	54	56	53	52	54	55	54	47	45	50	43	50	54	54	54	
Check	39	33	37	38	38	36	35	26	41	45	40	41	35	42	33	
Manure	48	52	48	51	47	47	45	40	42	44	40	42	41	45	39	
Compost	46	47	44	47	51	47	47	40	46	48	43	43	45	43	41	
LSD (0.05)	3	3	5	5	6	5	6	5	3	3	3	4	9	13	5	

Table 8. Correlation coefficients between chlorophyll meter readings of corn and plant dry weight or N uptake at the 10-leaf stage and at tasseling at Mead, NE.

Variable	Chlorophyll meter reading							
	1993		1994		1995		1996	
	10-leaf	tasseling	10-leaf	tasseling	10-leaf	tasseling	10-leaf	tasseling
	<i>r</i>							
10-leaf plant wt.	0.69**	—	0.75**	—	0.15	—	0.49**	—
10-leaf plant N	0.83**	—	0.86**	—	0.19	—	0.61**	—
Tasseling plant wt.	—	0.81**	—	0.70**	—	0.57**	—	0.64**
Tasseling plant N	—	0.72**	—	0.60**	—	0.68**	—	0.85**

**Significant at the 0.01 probability level.

nutrition during the growing season. Plant nutrition will eventually translate into grain yield and total biomass at harvest. Correlation coefficients between leaf chlorophyll at various times during the growing season with grain yield resulted in $r > 0.71$ in 1993, 1994, and 1996 (all significant at the 0.01 probability level; data not shown). In 1995, the correlation coefficients between chlorophyll meter readings on 3 August, 22 August, and 29 August and grain yield were 0.22, 0.65, and 0.41, respectively. In dry years, chlorophyll meter readings may not provide an indication of the yield level.

CONCLUSIONS

In 3 out of 4 years, beef cattle feedlot manure or composted feedlot manure left on the soil surface of no-till plots produced corn grain yields that were similar to those for plots in which the materials were incorporated. There was no apparent reason for greater corn yield for conventional compared with no-till treatments receiving manure or compost in 1996. It appears that surface application of beef cattle feedlot manure or composted manure did not result in significant N losses. This is because N compounds in beef cattle feedlot manure or compost are mainly organic forms and contain only small concentrations of $\text{NH}_4^+\text{-N}$ (which is subject to volatilization loss). Organic sources that contain a large concentration of $\text{NH}_4^+\text{-N}$ should be incorporated after application to minimize N loss. Nitrogen uptake by corn generally followed the same trend as grain yield, indicating that N availability from manure or compost followed the same pattern throughout the growing season in all years except 1995. In the drier 1995, early corn growth did not translate into greater grain yield. Averaged across years, fertilizer application resulted in greater grain yield than manure or compost. This was primarily because of significantly less corn yield for manure or compost than that for fertilizer treatment in the no-till in 1996. Additional research is needed to determine the amount of manure and compost N that becomes plant-available under different environmental and soil conditions so that these resources can be effectively utilized for crop production without adverse effects on the environment.

Stalk $\text{NO}_3^-\text{-N}$ concentration indicated excess soil $\text{NO}_3^-\text{-N}$ in the fertilized plots, but not in manure or compost plots in the dry year (1995). In a dry year, conversion of organic and $\text{NH}_4^+\text{-N}$ to $\text{NO}_3^-\text{-N}$ is slowed when manure and compost are applied. Chlorophyll

meter readings were very good indicators of plant growth and N uptake in all years except in the dry year of 1995. Water stress after the 10-leaf stage in 1995 resulted in chlorophyll meter readings that were not correlated with final N uptake. Water stress is a more dominant factor than N deficiency, and so chlorophyll meter readings may not be a good indicator of plant N status in water stress years.

REFERENCES

- Binford, G.D., A.M. Blackmer, and N.M. El-Hout. 1990. Tissue test for excess nitrogen during corn production. *Agron. J.* 82:124–129.
- Conservation Technology Information Center (CTIC). 1997. National crop residue management survey. Purdue Univ., West Lafayette, IN.
- Doran, J.W., and D.M. Linn. 1994. Microbial ecology of conservation management systems. p. 1–27. *In* J.L. Hatfield and B.A. Stewart. Soil biology: Effects on soil quality. *Advances in Soil Science*. Lewis Publ., Boca Raton, FL.
- Eghball, B., and J.F. Power. 1994. Beef cattle feedlot manure management. *J. Soil Water Conserv.* 49:113–122.
- Eghball, B., and J.F. Power. 1999. Phosphorus and nitrogen-based manure and compost application: Corn production and soil phosphorus. *Soil Sci. Soc. Am. J.* 63:895–901.
- Eghball, B., J.F. Power, J.E. Gilley, and J.W. Doran. 1997. Nutrient, carbon, and mass loss of beef cattle feedlot manure during composting. *J. Environ. Qual.* 26:189–193.
- Gilbertson, C.B., T.M. McCalla, J.R. Ellis, and W.R. Wood. 1971. Characteristics of manure accumulations removed from outdoor, unpaved beef cattle feedlot. p. 56–59. *In* Livestock wastes management and pollution abatement. *Proc. International Symposium on Livestock Wastes*, Columbus, OH. ASAE, St. Joseph, MI.
- Gilbertson, C.B., F.A. Norstadt, A.C. Mathers, R.F. Holt, L.R. Shuyler, A.P. Barnett, et al. 1979. Animal waste utilization on cropland and pastureland: A manual for evaluating agronomic and environmental effects. *Utilization Res. Rep. 6*. USDA, Washington, DC.
- Joshi, J.R., J.F. Moncrief, J.B. Swan, and P.M. Buford. 1994a. Long-term conservation tillage and liquid dairy manure effects on corn: I. Nitrogen availability. *Soil Tillage Res.* 31:211–224.
- Joshi, J.R., J.F. Moncrief, J.B. Swan, and G.L. Malzer. 1994b. Long-term conservation tillage and liquid dairy manure effects on corn: II. Nitrate concentration in soil water. *Soil Tillage Res.* 31:225–233.
- Krause, K.R. 1991. Cattle feeding, 1962–1989. Location and feedlot size. *AER 642*, USDA Econ. Res. Serv., Washington, DC.
- Overcash, M.R., F.J. Humenik, and J.R. Miner. 1983. Livestock waste management. vol. I. CRC Press, Boca Raton, FL.
- Rynk, R., M. van de Kamp, G.B. Willson, M.E. Singley, T.L. Richard, J.J. Kolega, et al. 1992. On farm composting. *Northeast Regional Agric. Engr. Serv.*, Ithaca, NY.
- SAS Institute. 1985. SAS user's guide. SAS Inst., Cary, NC.
- Schepers, J.S., D.D. Francis, and M.T. Thompson. 1989. Simultaneous determination of total C, total N, and ^{15}N on soil and plant materials. *Commun. Soil Sci. Plant Anal.* 20:949–959.
- Sims, J.T. 1987. Agronomic evaluation of poultry manure as a nitrogen source for conventional and no-tillage corn. *Agron. J.* 79:563–570.

Sweeten, J.M. 1988. Composting manure and sludge. p. 38–44. Proc. Natl. Poultry Waste Management Symp., Columbus, OH. 18–19 Apr. 1988. Ohio State Univ., Columbus.

U.S. Department of Agriculture. 1975. Minimum tillage: A preliminary technology assessment. W.B. Back (assessment leader). Office of Planning and Evaluation, USDA, Washington, DC.

Varvel, G.E., J.S. Schepers, and D.D. Francis. 1997. Chlorophyll meter and stalk nitrate techniques as complementary indices for residual nitrogen. J. Prod. Agric. 10:147–151.

Woodruff, N.P., L. Lyles, J.D. Dickerson, and D.V. Armbrust. 1974. Using cattle feedlot manure to control wind erosion. J. Soil Water Conserv. 29:127–129.

Statement of Ethics

American Society of Agronomy

Members of the American Society of Agronomy acknowledge that they are scientifically and professionally involved with the interdependence of natural, social, and technological systems. They are dedicated to the acquisition and dissemination of knowledge that advances the sciences and professions involving plants, soils, and their environment.

In an effort to promote the highest quality of scientific and professional conduct among its members, the American Society of Agronomy endorses the following guiding principles, which represent basic scientific and professional values of our profession.

Members shall:

1. Uphold the highest standards of scientific investigation and professional comportment, and an uncompromising commitment to the advancement of knowledge.
2. Honor the rights and accomplishments of others and properly credit the work and ideas of others.
3. Strive to avoid conflicts of interest.
4. Demonstrate social responsibility in scientific and professional practice, by considering whom their scientific and professional activities benefit, and whom they neglect.
5. Provide honest and impartial advice on subjects about which they are informed and qualified.
6. As mentors of the next generation of scientific and professional leaders, strive to instill these ethical standards in students at all educational levels.

Approved by the ASA Board of Directors, 1 Nov. 1992